JOURNAL
OF THE
WASHINGTON ACADEMY OF SCIENCES

VOL. 13 JANUARY 19, 1923 NO. 2

PHYSICS.—*Notes on the electric heating of calorimeters.*[1] WALTER P. WHITE. Geophysical Laboratory, Carnegie Institution of Washington.

Various systematic errors in calorimetry, especially those in the difficult heat capacity determination, are diminished or removed if the calorimeter is used to compare two thermal quantities, one of which is a standard. It now seems that such comparison methods, with rare exceptions, should be regarded as the normal thing in accurate calorimetry..

A fundamental standard should be above suspicion, hence the standard adopted should possess to the full the precision of the *comparative* calorimetric measurements. This is much higher than may generally be recognized. More than ten years ago calorimeters in two different laboratories showed a precision, i.e., an agreement, of 20 to 30 per million. It will hardly do to assign such a value for the probable final accuracy of a calorimetric experiment at present, but it is possible, under favorable conditions often attainable, and with no great amount of adjustment or experimenting, to secure, as far as the calorimeter itself is concerned, a precision of 100 per million, which would usually mean a like final accuracy if a comparison method is used. The standard for comparison should be safely more accurate than this, say to 30 per million.

Except in certain specific heat determinations, this standard of comparison must be a quantity of heat. Of the two available standards, mechanical and electric, the electric is unquestionably of preponderant practical value. It is really the standard in most cases at the

[1] Received December 20, 1922.

present time,[2] while it vies with heat of chemical reaction as a convenient secondary standard.

The present paper deals with some features of electric standardization which need attention in working to 30 per million.

It seems proper to take as the standard form of electric heating the well known method of measuring the time, the current through the heating coil, and the voltage drop across it; hence, for instance, if the resistance of the coil is used directly, it is to be measured between points which would be suitable for the attachment of the potential leads in the standard method. It is often desirable to make the time of heating as short as 3 minutes.

The special topics to be treated here are: I, the conduct of the determinations, and, II, the error from heat produced in the leads. In conducting the determinations it is necessary to deal with: A, the variety of observations, and B, the variations in the heating currrent.[3]

I, A. Management of the Observations

A second observer, with complete apparatus, can take care of the electric energy readings, including the time, so that the calorimeter can be observed as usual. A single practised observer, with good apparatus, can also do all the work alone if the calorimeter temperature is read electrically; most simply if a potentiometer can be used for all the measurements. A superior method, however, for fluid-filled calorimeters and heatings not over 5 minutes long, is to calculate the average calorimeter temperature during the heating, by means of observations made immediately before and after. It evidently makes the second observer quite superfluous, and enables a single one to give more complete attention to the energy readings. It therefore seems to deserve examination.

[2] To define the calory electrically, (as, say, 4.183 joules), is really only to recognize a situation already existing. Such recognition, as soon as it becomes general, will put an end to the use of the needless multiplicity of "calories" (15-degree calory; 20-degree calory, etc.) which now inconveniences us, since the only excuse for more than one standard is uncertainty as to the exact ratio between values determined by means of water at different temperatures. Few, if any existing results obtained in water-derived calories are accurate enough to suffer appreciable loss of accuracy through restatement in electric calories, while electrically derived results might often lose by the opposite transformation.

All this is aside from the question whether heat is to be stated in terms of calories of approximately 4.183 joules, or in joules directly.

[3] More difficult is knowing the values of the auxiliary resistance coils concerned in the energy measurement. This, however, has been adequately treated elsewhere.

Indirect Method for Finding the Thermal Head

The conditions on which the calculation method has to be based are as follows:

It will be convenient to treat first the case where the thermal head is practically zero at the beginning of the heating. If OA in fig. 1 represents the course of the calorimeter temperature before the heat is turned on at the time of A, for the time T, $= AB'$, then ABM may represent the temperature corresponding to the energy which has been given to the calorimeter. The temperature read is caused to vary from this simple scheme by two things, first the lag, and then the thermal leakage.

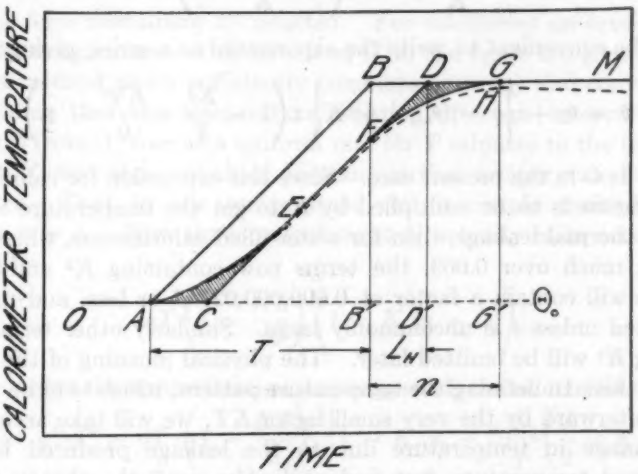

Fig. 1

The lag alone would make the temperature follow the line $AEFG$, which, if the lag is not unusually large, may with quite negligible error be taken as coincident between two points, E and F, with a line CD, parallel to AB, and at a point G with BM. Then the horizontal distance AC, $= BD$, represents the time L_H, the lag of the calorimeter temperature behind the energy supply. The shaded areas ACE and FDG are equivalent, hence the mean temperature and consequently the mean thermal head will be just the same if the line followed is $ACDM$, and this will be taken as the result of the heating.

This temperature pattern is further modified by the thermal leakage which it itself causes. The modification is merely a fall of temperature everywhere proportional to the actual thermal head, and giving that when superposed on the pattern $ACDM$.

For calculating this, the only measurements needed during the calibration are two, of calorimeter temperature or thermal head, one before the heat is started, the other long enough after its end to allow the difference between the converging lines DG and FG to become negligible. These data may then be used in accordance with the result of the following demonstration:

If q is the temperature rise corresponding to the heat supplied per minute, A the jacket temperature, and K the leakage modulus,[4] the temperature, neglecting lags, is easily shown to be:

$$\theta = \frac{q}{K} + A + \left(\theta_o - \frac{q}{K} - A\right)e^{-Kt} \qquad (1)$$

It will be convenient to write the exponential as a series, giving:

$$\theta = \theta_o + \left\{q - (\theta_o - A)\,K\right\} t\left(1 - \frac{Kt}{2} + \frac{K^2t^2}{6} - +\right) \qquad (2)$$

$\theta_o - A$ is O in the present case. Since this expression for calorimeter temperature is to be multiplied by K to get the temperature change due to thermal leakage, then for water-filled calorimeters, where K is seldom much over 0.003, the terms now containing K^2 and higher powers will contain a factor of 0.000,000,027 t^2 or less, and may be neglected unless t is uncommonly large. Similarly other terms containing K^2 will be omitted later. The physical meaning of the omission is this: In defining the temperature pattern, which is to be multiplied afterward by the very small factor KT, we will take account of the change in temperature due to the leakage produced by the impressed temperature, but find negligibly small the change in the leakage caused by the change due to the leakage.

If n denotes the time from the end of the heating to the first direct thermal head measurement afterward, represented by BG, then the time from D to G is $n - L_H$. Thermal head is the same as the temperature rise above θ_o since it was taken as zero for $\theta = \theta_o$. On account of thermal leakage, the temperature after $T + L_H$ minutes is not $D'D$ which equals qT but, by (2) $qT - qT\,\frac{KT}{2}$; and after $n - L_H$ minutes more is still lower, or, say, $G'H$. This is the temperature actually observed. Then the *true* integrated thermal head, $\phi T'$,

[4] Thermal leakage modulus, temperature fall per minute per degree of thermal head. Thermal head, mean effective temperature difference between calorimeter surface and surroundings.

to the time of G is the head during the temperature rise plus that during the approach of equilibrium, or:

$$\phi T' = \int_0^T \left(qt - qt\,\frac{Kt}{2}\right) dt + \left[qT - \frac{qKT^2}{2}\right] \int_0^{n-L} (1 - Kt)\, dt$$

which gives for the true integrated thermal head for the interval $T + n$:

$$\phi T' = qT \left\{\frac{T}{2} - \frac{KT^2}{6} + (n - L) - \frac{KT}{2}(n - L) - \frac{K}{2}(n - L)^2\right\} \quad (3)$$

with a term containing K^2 omitted. For *calculating* an *equivalent to this* the temperatures at times A and G' in the figure are given. It is then a method which sufficiently combines accuracy and convenience to assume that the temperature, starting after an interval of L_H minutes from A, rose at a uniform rate for T minutes to the temperature $G'H$, and then remained constant at that temperature for $n - L$ minutes. That is, the temperature rise is simply multiplied by $\frac{1}{2}\ T + n - L$. Now the temperature at H actually is, in accordance with (2):

$$qT\left(1 - \frac{KT}{2}\right)\Big(1 - K\,(n - L)\Big) \quad (4)$$

Hence, using the approximation just suggested, the calculated thermal head is: $\phi'' T' = qT \left(1 - \frac{KT}{2}\right) \left\{1 - K\,(n - L)\right\} \left(\frac{T}{2} + n - L\right)$, which is, again omitting terms containing K^2:

$$\phi'' T' = qT \left\{\frac{T}{2} \frac{KT^2}{4} + (n - L) - KT\,(n - L) - K\,(n - L)^2\right\} (5)$$

The difference between this and (3) is the error of the approximation made in calculating. It is:

$$\delta\,(\phi T') = qTK \left\{\frac{T^2}{12} + \frac{T\,(n - L)}{2} + \frac{(n - L)^2}{2}\right\} \quad (6)$$

The calculated thermal head is too small by this amount. A glance at (3) shows that this error is over half of the real change in $\phi T'$ due to the leakage.

With $T = 4$, $n - L = 1$, $K = 0.003$, this error causes a final error of 0.000,036 qT, which is safely negligible even in work of 0.1 per mille

accuracy, but can also be corrected for with ease. $n - L$ should usually be less than half a minute. With the large values of K characteristic of some aneroid calorimeters, closer approximations would be needed.

In using this method the value of L, the lag represented by BD in fig. 2, should be known rather accurately, since this affects directly the time assigned to the higher temperature, and so is in effect multiplied by $K\Delta\theta$ in getting the thermal leakage. Hence for 0.03 per mille precision, that is, for security in 0.1 per mille precision, L, if K is 0.003, should be known to 0.01 minute, like any other lag affecting the whole calorimeter. A very satisfactory way to determine it is this: Make a series of blank heatings, observing only thermal head or calorimeter temperature, as frequently as, say, every 15 seconds. Then, as in any regular calorimetric determination, find, from the calorimeter temperature, the total heat supplied, and also find the thermal leakage up to the time of each 15-second reading, which is not nearly so troublesome as it may sound. Then, knowing the total heat, the fact that it was supplied uniformly, and the thermal leakages, compute the calorimeter temperature corresponding to the heat actually in the calorimeter at each reading. Comparing these with the observed temperatures gives a series of values for the lag, whose average is comparatively unaffected by the fluctuations of the rapidly rising temperature, and of course has the thermal leakage eliminated. The same data give a check of correction (6) for the apparatus and conditions employed. The total leakage is usually so small that a predetermined value of K is quite good enough, hence no rating periods ("after periods") are needed. In a number of tests of this procedure the check of (6) was seldom out by more than 1/3 of (6) which, in this case, was about the uncertainty of a single reading, and corresponded to 0.25 second during the rapid rise of temperature. The main probable cause for the discrepancies observed was the fluctuation of the rising temperature as read. This seems to show that where the lag is constant, the method of calculation here given, corrected by means of (6), will probably give more accurate results in actual calibrations than observations of ϕ. Readings once a minute, however, though less accurate, will, with reasonably good stirring, be sufficient for observing the thermal head; this is why it can be observed along with the electric energy.

Such readings may be preferable or even necessary if the blank heatings have shown the lag to be variable.

Blank heatings will also enable an empirical expression, a substitute for (6), to be found in cases where the lag is large, and where, conse-

quently, the two triangular areas are not independent of each other, and (6) does not hold. Indeed, blank heatings alone might be used in most cases. The preceding analysis, however, seems generally useful in giving an idea of the sources of error, and of the precautions that must be taken if there is an initial thermal head, or if the jacket temperature changes, matters whose purely empirical investigation will generally be very tedious and of inferior accuracy.

Extension for Initial Thermal Head

An initial thermal head, that is, a difference between calorimeter and jacket at the time, A, will cause a thermal leakage which will be simply added to the one already considered, due to the heating. This leakage may properly be taken as modifying the initial thermal head which causes it, but as having no other effect. The two thermal heads, each with its resultant leakage, may therefore be considered as separate. The measurement made at the time of H in fig. 1, however, takes them together. If the simple approximation of (5) is then used the rise due to the heating, to which the approximation is applied, is underestimated, and no account is taken of the change in ϕ_o as such. Greater accuracy would therefore be obtained by adding again the fall in ϕ_o, multiplied by $\frac{T}{2} + n - L$, and subtracting the (integrated) real loss of thermal head due to the diminution of ϕ_o. The fall in ϕ_o is $\phi_o K (T + n)$, the loss of integrated thermal head from it is $\phi_o K \left(\frac{T+n}{2}\right)^2$; the application of the method of (5) is thus easily found to give a result which is too low by

$$\phi_o K \left(\frac{n}{2} - L\right) (n + T) \qquad (7)$$

in addition to (6).

Change in jacket temperature can be similarly treated. If the jacket is electrically heated, so as to give a nearly adiabatic method, its lag, as usually in adiabatic work, will be as important as the lag in the calorimeter.

Initial Change in Heating

When the current is first turned into the heater the resulting change of temperature of the wire will generally cause an initial change of resistance and the value for the first few seconds will be different from

that measured. If the resistance for the first 10 seconds of 3 minutes differs by 1 per mille from the later, measured value, the discrepancy is appreciable in work of 0.1 per mille precision. Changes greater than this are possible, even in constantan wire, if the attempt is made to run at anything like the highest safe temperature. Although difficult to follow during a regular run, the change can easily be measured, and should be, by special experiments where nothing else is attempted, but subsequent variations in it will of course cause error. Unlike the lag effect already discussed, it has no tendency to cancel itself, since the reverse change in resistance comes only after the current has ceased to flow. To keep the heater coil running at a low temperature diminishes this error, and also that from loss of heat along the leads.

I, B. DEALING WITH UNSTEADY BATTERIES

Unsteady batteries are scarcely compatible with the very highest precision; with them the best results are obtained by some departure from standard procedure. (1) Very frequent, uninterrupted measurements of current or voltage tend to diminish the error from irregularly varying voltage, but demand either two observers with complete sets of apparatus, or else reliance upon the constancy of values for coil resistance, correlated with current and calorimeter temperature, determined by separate special experiments. (2) The voltameter, giving directly the product of current and time, handles perfectly the most sudden and irregular fluctuations[5] of current, and still leaves the observer's time free for other things. This time can be employed for measuring the coil resistance by a Wheatstone bridge, using the heating current itself as the bridge current.[6] This involves a loss of simplicity in the electric circuit, but is of advantage if it is desired to shunt part of the current by the heater, in order to give the voltameter the relatively large current which promotes accuracy with it; the Wheatstone bridge measurements can also be used as measurements of the shunt ratio. A further disadvantage is the relatively long time, 20 minutes at the very least, needed for high precision with the voltameter.

[5] There is evidently an error from very large fluctuations, owing to the fact that the heat is as the square of the current, but this error is usually quite negligible, and if not, can be avoided by a little coarse voltage regulation. The voltameter result is also sufficient when accompanied only by *accurate* measurements of voltage. In this case the voltameter makes the time measurement unnecessary, but does not deal well with voltage fluctuations.

[6] This has been done; the reference is not at hand. The coil resistance will vary very much less than the current, hence is far more easily measured when the current is unsteady.

II. ERRORS CONNECTED WITH THE LEADS

The proper place to put the potential terminals, whose location determines the amount of heat that comes into the measurement, is not at the ends of the constantan wire,[7] but outside the calorimeter altogether, at a point such that the heat generated in the lead wire between it and the calorimeter equals that flowing from the wire to the calorimeter. In general, the accurate location of this point is rather difficult, but it becomes easy if the heat given to the air can be neglected, since the proper point is then simply the middle of the free portion of the leads. The heat given to the air is easily found to be:

$$QX - \frac{Q}{\mu} \tanh \mu X \qquad (8)$$

where Q is the heat generated in each centimeter of the wire, $2X$ is the length of each lead between surfaces, and the parameter $\mu = \sqrt{\frac{EP}{AK}}$, where E is emissivity, K thermal conductivity, A area, P perimeter. Langmuir's stationary surface layer rule has been used to get E.[8] Relatively crude data are here sufficient, since the attempt is only to determine when certain quantities are negligible, not to compute appreciable corrections.

One ampere at 110 volts generates 4733 calories in 3 minutes. In 1 cm. of No. 24 lead wire (about 0.5 mm. in diameter) it would generate 0.03626 calories, which number can conveniently be doubled, since we are dealing with a pair of leads, so the heat is 0.073 calories per cm. of lead length. For this wire, μ, calculated as in the paper just referred to, may be taken as 0.28, and 0.51 for No. 30 wire, while 0.16 was given for No. 18. We then have the values in table 1 for heat given to the air and not delivered at the ends, in 3 minutes.

It thus appears that, when the voltage across coil terminals is 110, and the current 1 ampere, with No. 30 leads 4 cm. long, No. 24 leads 10 cm. long, and No. 18 leads 28 cm. long, the heat lost to the air from the leads may be simply neglected. This is true even if the potential leads increase the loss to the air, which they will scarcely do if wound helically on the others and cemented there by shellacking. Moreover, the heat that goes into the air will in part return to the calo-

[7] Cf. H. C. Dickinson, Combustion calorimetry and the heats of combustion of . . . . Bull. Bur. Standards 11: 222, 1914.

[8] Cf. Walter P. White, The conditions of calorimetric precision. J. Am. Chem. Soc. 40, 1882, 1918.

rimeter, so the final loss is less than given in the table. On the other hand, the wire will not take the calorimeter temperature just at the surface, and the point of mean effective contact may be 1 or 2 cm. within. This will make the air loss as great as if part of the extra length were added to the wire in air, so it will be safer, in applying table 1, to take 2X as 2 cm. more than the free length of the wire.

TABLE 1.—APPROXIMATE LOSS TO THE AIR, IN CALORIES, IN 3 MINUTES FROM HALF OF 2 LEAD WIRES OF LENGTH 2X EACH.

	X, cm.	DIAMETER, mm.		
		1	0.5	0.25
1 ampere	1	0.00016	0.0018	0.023
	2	0.0012	0.014	0.14
	3	0.0039	0.04	0.35
	4	0.0086	0.08	
	5	0.016	0.13	
	10			
	14	0.14		
5 amperes	1			0.57
	2.5		0.62	
	6.5	0.75		
5 amperes	0.5			0.14
	1.5		0.15	
	3.5	0.148		

Of more importance may be the effect of the uncertain contact on the flow of the heat that does not go into the air. If the contacts are symmetrical no error results; if one is effectively 1 cm. deeper than the other, that is equivalent to a displacement of 0.5 cm. in the potential lead attachment. This, for 1 ampere, 110 volts, gives a systematic error of about 8 per million of the total heat with No. 24, and of only 30 per million even with No. 30 leads.

Thus with a little care even No. 30 wire will usually make satisfactory leads for a heater that can raise a liter calorimeter 5° in an appropriately short time. Coiled leads of larger wire are safer, but less convenient. Direct leads of larger wire increase various undesirable leakages unnecessarily.[9] If 5 amperes is used the heat produced in the wires is 25 times as great, but at 110 volts the allowable leakage

[9] For a precaution necessary with No. 18, or even with No. 24 leads see Walter P. White, op. cit., p. 1884.

is 5 times as great; not so if the 5 amperes is used to give the same heat, at lower voltage. The limits of toleration of air loss for each case are shown in the second and third sections of table 1. For a given size of wire the proportional error is constant for a given coil resistance, regardless of current or voltage. The error from lack of symmetry in the thermal contacts at the two ends of the free portion of the leads may also become serious. For 1 cm. difference, 5 amperes and 110 volts, this error is nearly 40 per million for No. 24 wire, which therefore seems the very smallest that should be used for 100 per million precision with coils of as low resistance, 22 ohms, as is required for this current and voltage. Another advantage in using slender leads is that they can be removed from the calorimeter with but little change in the total heat capacity. This is assuming that the heater itself remains, so that any uncertainty there may be as to its heat capacity does not affect the application of the result of the calibration.

The conductivity of the potential leads may disturb the symmetrical distribution of the heat generated in the current leads. This can be avoided by making the potential leads symmetrical with respect to calorimeter and jacket, as by having one lead run from the neutral point into the calorimeter, there turning around (still insulated electrically) to run entirely across the gap and out through the jacket.

Thus far the upper part of the heater case and the leads within it have been taken as at the calorimeter temperature, except for a slight correction due to the effect of heat coming in from the free part of the leads. If the upper part of the case or the leads are heated above the calorimeter temperature by the heating coil itself, the only way of avoiding an uncertain correction appears to be to run the leads a sufficient distance in close contact with some conducting body which, by immersion in the water or attachment to the calorimeter wall, or in some other way, is kept at the calorimeter temperature. If only the leads are heated and not the top of the case, it may be sufficient merely to have the leads run a considerable distance before leaving the case.

The required distances can be calculated by the formulas of the section on Conduction through the Jacket, in the paper already referred to. For example, the following results were thus obtained for No. 24 wire, running 5 cm. in the case and 6 cm. through the air to the jacket. For this wire μ in air has been taken as 0.28. For the wire in close thermal contact with a plate on one side only, as it would be if wound around a central mica strip in a flat case, μ can be taken as 0.040 Then if θ_0 is the temperature of the inner end, next the heater coil, of the 5 cm. of wire, referred to the calorimeter-air-jacket temperature as

zero, the temperature where the wire enters the air is 0.18 θ_0, and the heat carried away by 2 leads in 3 minutes is 0.037 θ_0 calories. For 110 volts and 1 ampere the systematic error of such an arrangement with the heating coil running at 120° would be about 1 per mille, and the coil must heat less than 3° to safely avoid systematic error in work of 0.1 per mille precision. By doubling the length of lead in the inclosure the permissible heating is increased, somewhere near 8 times. A doubling of μ would have an identical effect, but would be rather hard to secure with the same size of wire. It therefore seems that it would generally be very desirable to insert portions of finer lead wire next the coil, using enough larger wire further out, but well within the calorimeter, to dissipate to the calorimeter the heat generated in the fine wire. Advantageous dimensions can be calculated from the data already given. The insertion of too much copper resistance gives the heater resistance too great a temperature coefficient. There is little danger of trouble from this cause, however, as long as its possibility is not overlooked.

The assumption of temperature equality between calorimeter and jacket, used in this section, is justified as follows: The temperature distributions and flows existing at any time are the resultant of the electric heat and of the jacket-calorimeter difference, and may be resolved into components due to these different sources. Since by a well known principle the resultants of such components can be obtained by simple addition, and since the results of the calorimeter-jacket difference are taken care of in the regular procedure, we may treat the electric effects alone, as if the others were non-existent.

BOTANY.—*The genus* Microstaphyla.[1] WILLIAM R. MAXON, National Museum.

Among the many diverse ferns comprising the tribe Acrosticheae of the family Polypodiaceae one of the most interesting of all is the diminutive plant of St. Helena first described by the younger Linnaeus in 1781 as *Adiantum furcatum*, and later by Jacquin as *Osmunda bifurcata*. By the older writers it was placed at one time or another in no less than seven different genera, before serving as the type and sole species of *Microstaphyla* Presl. This, like so many other of Presl's genera, was submerged in synonymy by later writers. In 1895 a closely related Bolivian plant, with simple instead of pinnate sporo-

[1] Published by permission of the Secretary of the Smithsonian Institution. Received November 29, 1922.

phylls, was described by Mrs. Elizabeth G. Britton as *Acrostichum moorei*. Since then the systematic status of *Microstaphyla* and the nomenclature of the Bolivian plant have received a good deal of attention at the hands of Underwood[2] and Christ.[3] Christ comes to the conclusion that, notwithstanding the close general agreement in dissected foliage leaves shown by the St. Helena and Bolivia species, the slender scaly rhizome and simple sporophylls of the latter plant form a definite connecting-link between *Microstaphyla* (in its original sense) and *Elaphoglossum*. The characters of *Rhipidopteris* and of certain small Andean species of *Elaphoglossum* are discussed in this connection, and both *Microstaphyla* and *Rhipidopteris* are reduced to the rank of subgenera under *Elaphoglossum*—the former to include the two species with pinnate sterile fronds, the latter those with palmately or flabellately divided sterile fronds. Nevertheless, both Hieronymus and Underwood have regarded *Microstaphyla* and *Rhipidopteris* as valid genera, and in this opinion the writer is obliged to concur. Christ's arguments lose none of their weight from the evolutionary standpoint; the question is merely upon the rank to be assigned to the forms as they exist today. In their peculiarly distinctive sterile fronds both *Rhipidopteris* and *Microstaphyla* depart too widely from simple-leaved *Elaphoglossum* to be retained in that genus.

Very recently a third species of *Microstaphyla* has been discovered in Colombia. This is described below. There is given also the principal synonymy of the two species previously known.

1. **Microstaphyla furcata** (L. f.) Fée, Mém. Foug. **7**: 45. *pl. 13*. 1857.
Adiantum furcatum L. f. Suppl. Pl. 447. 1781.
Osmunda bifurcata Jacq. Coll. Bot. **3**: 282. *pl. 20, f. 2*. 1789.
Acrostichum bifurcatum Swartz, Journ. Bot. Schrad. **1800**[2]: 13. 1801. Not *A. bifurcatum* Cav. 1799.
Gymnogramma bifurcata Kaulf. Wes. Farrnkr. 81. 1827.
Darea furcans Bory, Dup. Voy. Bot. **1**: 269. *pl. 35, f. 2*. 1828.
Olfersia bifurcata Presl, Tent. Pter. 234. 1836.
Polybotrya bifurcata J. Sm. Journ. Bot. Hook. **4**: 150. 1841.
Microstaphyla bifurcata Presl, Epim. Bot. 161. 1851.

Known only from St. Helena, where it has been repeatedly collected. Of the two specimens at hand, one is no. 420 of Cuming's historic collection; the other bears no collector's name.

The present species is too well known to require detailed discussion. Besides the illustrations above given, those of Schkuhr and Hooker may be

[2] Torreya **5**: 87–89. 1905.

[3] Bull. Herb. Boiss. II. **1**: 588–592. *text fig.* 1901; ibid. II. **3**: 148. 1903: Torreya **5**: 123–126. 1905.

cited.[4] Hooker's comments on Fée's error in associating with it the plant now called *Elaphoglossum dimorphum* (Hook. & Grev.) Moore are of interest.

2. **Microstaphyla moorei** (E. G. Britton) Underw. Torreya **5**: 88. 1905.
Acrostichum moorei E. G. Britton, Mem. Torrey Club **4**: 273. 1895.
Rhipidopteris rusbyi Christ, Farnkr. Erde 46. 1897.
Elaphoglossum bangii Christ, Mon. Elaph. 99. 1899.
Elaphoglossum moorei Christ, Bull. Herb. Boiss. II. **3**: 148. 1903.
Microstaphyla bangii Hieron. Bot. Jahrb. Engler **34**: 539. 1904.

Founded on specimens collected near Yungas, Bolivia, in 1890, by Miguel Bang (no. 558), of which two sheets are at hand. The specific name is in honor of Thomas Moore, whose fern collection in the Kew Herbarium is said to contain a specimen collected by Lechler "near Sachapata, on trunks of trees, and distributed as no. 2609, Plantae Perúvianae." Hieronymus also lists *Lechler* 2609 under this species, probably with correctness. An additional specimen has recently been received from Bolivia: On tree-trunks, among moss, Hacienda Simaco, on the trail to Tipuani, altitude 1,400 meters, January, 1920, *Buchtien* 5297; this agrees very closely with the Bang material.

It is to be noted that Hieronymus cites also a Colombian specimen, collected in 1882 by Schmidtchen, the exact locality not stated. This, which has not been seen by the writer, not improbably pertains to the next species.

3. **Microstaphyla columbiana** Maxon, sp. nov.

Plants terrestrial, entangled in a loose mat. Rhizomes wide-creeping, 30 cm. long or more, about 0.5 mm. in diameter, flexuous, sparingly branched, bearing a few distant roots, brownish, sulcate, flattish or irregularly triquetrous in drying, subpersistently paleaceous, the scales loosely appressed-imbricate, pale yellowish brown, membranous, translucent, 2 to 2.5 mm. long, narrowly deltoid-ovate, attenuate, attached above the closed sinus of the very deeply cordate base (the lobes widely overlapping), with a few, mostly basal teeth. Sterile fronds numerous, borne singly 1 to 5 cm. apart, ascending, 8 to 18 cm. long; stipes continuous with the rhizome, 3 to 7 cm. long, about 0.5 mm. thick, brownish and terete at the extreme base, upward greenish and compressed, slightly alate at summit, deciduously paleaceous throughout, the scales ovate-oblong, acute, often coarsely dentate; blades lanceolate, caudate, 5 to 11 cm. long, 2 to 3 cm. broad just above the base, essentially pinnate at base, nearly so throughout; pinnae 5 to 10 pairs, oblique, subopposite at base, mostly alternate above, distant (5 to 10 mm. apart on each side), linear-cuneiform, 1 to 3 mm. broad just above the narrowly decurrent base, dichotomously forked at or beyond the middle (the divisions 2 to 8 mm. long, the distal one usually the longer, one or both deeply retuse), or those toward the apex linear-subspatulate, merely retuse, the apical ones gradually reduced, finally evident as coarse distant serrations of the long-caudate tip; veins mostly arising in pairs at base of pinnae, once or twice forked, 4 branches usually occurring at middle of pinna, 2 extending to each division, clavate; leaf tissue glabrous, dull green, membrano-herbaceous, opaque, the venation seen with difficulty. Fertile fronds wanting.

[4] Krypt. Gew. *pl. 2;* Second Cent. Ferns, *pl. 91.*

Type in the U. S. National Herbarium, no. 1,140,001, collected in dense forest above La Cumbre, Department of El Valle, western cordillera of Colombia, at about 2,200 meters altitude, September 18, 1922, by Ellsworth P. Killip (no. 11365). The description is drawn partly from a second sheet of the type collection. Duplicates will be distributed to the Gray Herbarium, the New York Botanical Garden, and the Academy of Natural Sciences, Philadelphia, in whose interests also the recent botanical exploration in western Colombia was conducted under the leadership of Dr. F. W. Pennell.

Related to *Microstaphyla moorei*, which is distinguished readily, however, by (1) its oblong, non-caudate blades, the basal pinnae not reduced and the apical ones few and abruptly discontinuous; (2) its very much narrower divisions, these acute and invariably with a single veinlet; (3) its delicately membranous, translucent leaf tissue, the venation being readily evident without the aid of transmitted light. *M. moorei* is a more delicate plant than *M. columbiana* in every way; in some fronds all the pinnae are undivided. Fertile fronds of *M. columbiana*, unrepresented in the material at hand, are presumably similar in general form to those of *M. moorei*.

SCIENTIFIC NOTES AND NEWS

A recent circular to employees of the U. S. Coast and Geodetic Survey calls attention to tests made in the section of field records which indicate that mounted drawing paper in rolls fails to give flat surfaces when cut into lengths for immediate use. Due to unequal seasoning, surplus paper exists near the lengthwise edges of the rolls and this condition brings about a noticeable distortion in projections constructed on the sheets. In order to minimize this unequal seasoning it is suggested that entire rolls of mounted drawing paper, when received in the field, be immediately cut into sheets of suitable lengths for smooth plotting work and stowed face down in a ventilated drawer.

Final tests of the new field automatic tide gauge of the U. S. Coast and Geodetic Survey were made recently at the Lighthouse Wharf in Washington. These tests showed that this tide gauge will give thoroughly satisfactory records for use of hydrographic parties.

The Carnegie Institution of Washington will continue to cooperate in the seismologic work and investigation of crustal movement in California. Special attention will be paid to the development of new instruments for the measurement of small earth tremors. An interesting feature of the recent exhibit at the Institution was a map showing the location of faults in California. The production of this map was made possible by the cooperation of scientific and mercantile interests. It will be published in final form by the Seismological Society of America.

Two destroyers of the U. S. Navy are engaged in making sounding measurements off the west coast of the United States with the "sonic" sounding apparatus. Parallel runs are being made at distances of five or ten miles and soundings are taken up to the two thousand fathom mark. The object is a complete topographic map of that part of the bottom of the sea.

The Petrologists' Club met on Tuesday, December 19, at 8 p.m. Dr. N. L. BOWEN spoke on *The action of magmas on autolithic and xenolithic material.* He reviewed the various possible directions of crystallization and subsequent reaction between liquid and solid phases, and thus accounted for the various series of igneous rocks which are found in many localities.

Among those on the program of the thirty-fifth annual meeting of the Geological Society of America at Ann Arbor, Michigan, December 28–30, 1922, were the following members from Washington: M. AUROUSSEAU, N. L. BOWEN, WILLIAM BOWIE, ARTHUR KEITH, WILLIS T. LEE, and FRED E. WRIGHT.

At the twenty-fourth annual meeting of the American Physical Society at Boston, December 27–29, 1922, papers were given by the following representatives of Washington institutions: L. A. BAUER, P. D. FOOTE, F. L. MOHLER, W. J. PETERS, and FRANK WENNER.

Mr. M. G. DONK, for the last two years connected with the Edgewood Arsenal, Chemical Warfare Service, has joined the staff of the chemical division of the U. S. Tariff Commission. He will specialize in heavy chemicals.

Mr. CHARLES W. HOY of the Smithsonian Institution left Washington December 15 for a two years' trip in Central China, in the basin and mountains of the Yang-tse, devoting most of his time to collecting mammals, birds, and fishes.

Representative R. WALTON MOORE was appointed a regent of the Smithsonian Institution December 7.

Dr. BAILEY WILLIS, emeritus professor of geology, Stanford University, sailed for Chile January 11 to investigate the evidence of the recent earthquake, in response to an invitation sent to the Carnegie Institution of Washington through the Chilean Embassy.